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"Navigating Change: Evaluating Ductile Design Modifications in RC Framed Structures after IS 13920-1993 Revision"

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Abstract : IS 13920-2016 and IS 13920-1993 were used to compare the ductile design of RCC structures. The standard structural design and construction methods used in India have proved that they do not meet the basic seismic resistance criteria. One of the key issues that needs to be addressed is the use of ductile design and detailing methods in building structures. In general, the ductility of reinforced concrete structures is a concerning issue. To prevent seismic damage and life-threatening collapse, certain design considerations and reinforcing detailing can be applied in specific crucial spots of the structure.

For ductile detailing and design, an earthquake-resistant construction should follow IS 456 and IS 13920. When RCC framed constructions are given ductile detailing, they become moment-resisting frames. In the revised ductile detailing code, the structural design and detailing clauses have been updated, structures designed in the past using the old code lacked in design and detailing clauses for a high seismic force as compared to buildings analyzed under the revised IS 13920 codes.

A confinement zone in a structural member is a place where additional ductility is required, which can be achieved by reducing transverse reinforcement spacing. Greater ductility is necessary during an earthquake or any other reason for transverse deformation of the member. The concrete of the RC member experiences the maximum nonlinearity in its stress-strain response during an earthquake, hence the increased transverse reinforcement benefits in seismic energy dissipation. Common examples of confinement zones include column ends, beam ends, beam-column couplings, and other critical locations. As a result, additional limiting reinforcement is provided at these locations, usually in the form of closely placed ties.

If a significant amount of transverse reinforcement is required to achieve the shear strength requirements of beams and columns, such transverse reinforcement must be provided as per revised code, and special confining reinforcement is not required, according to the modified IS 13920.

***IndexTerms* - Seismic, Earthquake, IS 13920, IS 1893, IS 456, RC Structures, Ductility, nonlinearity, Ductile Detailing**

I.INTRODUCTION

The movement of tectonic plates in the earth's crust causes an earthquake, which results in intense ground shaking. In the last thirty years, moderate to severe earthquakes have struck the planet at 5- to 10-year intervals, causing catastrophic damage and casualties due to structural collapse, tsunamis, floods, landslides on weak slopes, and liquefaction of sandy soils. The construction of new cities in earthquake-prone zones has resulted in huge socio-economic losses around the world. As a result, it has been observed that in the past, these construction developments did not follow seismic code guidelines. The detailing techniques are easy, economical, and thoroughly discussed in the bureau of Indian standard code of practice (IS 13920). Following the earthquakes that occurred after the release of IS 13920-1993 (particularly the 1997 Jabalpur, 2001 Bhuj, 2004 Sumatra, and 2006 Sikkim earthquakes), it was felt that the code needed to be improved further. This research proposes a comparison of multi-storey framed buildings with their column c/s, aspect ratio, and minimum requirement of beam-column junction using the equivalent static method as per the specifications of IS 13920-2016 and IS 13920-1993.

Since the 19th century, reinforced concrete has been a key construction material for multi-storey buildings. In the Middle East, many residential and commercial buildings include parking in the basement as well as at first floor. These stories are referred to as soft stories since they are 80 percent less rigid than the storey above. As a result, earthquakes make soft stories more vulnerable. The most popular type of earthquake-resistant structure is a reinforced concrete frame structure.

The primary objective of all structural design methods employed in the analysis and design of structures is to effectively transfer gravitational loads. Dead loads, live loads, and snow loads are the three most common loads caused by gravity. Buildings are also subjected to lateral loads induced by wind, blasting, or earthquakes, in addition to these vertical stresses. High stresses, sway movement, and vibration can all be caused by lateral loads. As a result, the structure must be strong enough to withstand vertical loads while also being stiff enough to withstand lateral stresses..

Wind loads, earthquake forces, blast forces, and other transverse loads are becoming more important, and practically every designer is faced with the challenge of providing enough strength and stability against horizontal loads. However, structural engineers have significant hurdles in minimizing these losses through good structure design and detailing. Using state-of-the-art in earthquake engineering design and construction approaches, life dangers and damage to reinforced concrete buildings will be reduced. Following each devastating earthquake, various damages are detected. These damages reveal that the design and construction methods need to be improved, according to the research. The intensity of the damage is determined by the earthquake's magnitude, focus and distance from the epicenter, as well as the soil strata on which the structure is built.

Reinforced concrete framed structures are designed to resist flexural, axial, and shearing movements during severe earthquake ground shaking. Based on their proportioning and detailing, many seismic design codes classify these frame structures into distinct ductility classes with varied response reduction factors. Aside from drift control, determining the seismic performance of designed buildings is crucial. It should be noted that while all codes provide processes for assessing drift and determining the permitted limit of drift, there are variances owing to structural member stiffness.

Figure 1 Structural Damages Caused by Earthquake

II. OBJECTIVES

The primary goal of this research is to determine the seismic response of multistorey RC buildings using ETABS 2019 for various revised clauses in IS 13920-1993.

The dissertation's objectives are as follows:

1. To evaluate the influence of the 2016 revision of IS 13920 on multi-storey RC framed building through analysis and design using commercial software ETABS 2019.
2. To determine the dynamic response of an RC Framed structure when ductile detailing is being used.
3. To Perform a parametric analysis of the time period, the base shear, the storey drift, and the roof displacement.
4. To examine RC-framed buildings in seismic zone III, India using revised IS 13920 specifying clauses for beam-column dimensions.
5. Recommend strategic locations for ductile detailing for static and dynamic response under critical loading situations.

III.LITERATURE REVIEW

Dr. Jain et al. [1] conducted a comprehensive review of IS: 13920 – 2016 and came to the following conclusion. Several explanations and provisions addressing the flexure and shear strength of beam-column joints were incorporated in the final Code. There are a number of typos. Experimentation and nonlinear dynamic analysis capacity are mentioned in the code. Although IS 13920-2016 has incorporated various figures and clauses from ACI 318, including the confinement steel for circular columns, there is no basis for not updating the confinement steel in rectangular columns phrase, which is repeated three times in the ACI.

Dr. Gupta et al [2] published a Revision of IS 13920 – A Review (Part 1 and 2) that finds the focus was on the shear strength of concrete in the joint as well as the shear stress requirement of the junction (Column-Beam Joint). Based on the H/L ratio, the new code divides shear walls into three categories: squat, moderate, and thin. Each category has its own strengthening requirements. 'Gravity Columns' are now available, for columns that are not part of the lateral load resisting system. In seismic zones III, IV, and V, the revised code suggests that all ductile design and detailing be followed, but in seismic zone II, it is optional.

Sudhir K. Jain [3] published Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces Code of Practice (IS 13920 2016) Proposed Modifications and Commentary in 2019. They also compared each alteration in each clause, according to Durgesh C Rai.

Shah et al. [4] compared the ductile design of columns using the new IS 13920 – 2016 and the old IS 13920 – 1993 standards. Beam-column joints in moment resisting frames have generally been overlooked in the design process, although the individual connecting elements, namely the beam and column, only in the 1970s did research on beam-column junctions in reinforcing concrete moment resistant frames begin. IS 13920 was revised in 1993 to include provisions for the design of beam-column joints. The design of beam–column joints has gotten a lot of attention. And it's more efficient for high-rise structures. The base shear is raised by employing amended clauses of IS 13920 – 2016, namely column C/S, aspect ratio, column minimum dimension, and beam Column joint shear design. With the new IS requirement, the time period, storey drift, and roof displacement all drop.

Danish Khan, [5] conclude that the seismic performance of three different reinforced concrete frames with and without ductile detailing is analyzed utilizing a non-linear static approach in a comparison study for seismic Performance of Ductile and non-ductile RC frames. The inclusion of ductile detailing increases the capacity of the reinforced concrete frame, as shown by the pushover curves and storey displacement plots.

IV.SEISMIC EVALUATION METHODS

It is necessary to know how the building reacts during an earthquake in order to improve its performance during an earthquake, and this necessitates a seismic study of the structure. Buildings are seismically analyzed using two methods: static analysis and dynamic analysis. The static analysis does not provide an accurate representation of how the structure would react during an earthquake, but it does provide approximate forces and displacements. The results of the dynamic analysis are relatively correct.

4.1 PHILOSOPHY FOR SEISMIC DESIGN

The design philosophy can be divided into three categories in general.

1. Serviceability limit state or Minor damage philosophy
2. Damage controlled limit state or reparable damage philosophy
3. Survival limit state or Irreparable damage philosophy

The load-carrying structures (such as the slab, beam, column, and footing) shall not be harmed by mild tremors, according to the serviceability limit state. Non-load-bearing structures, on the other hand, may suffer damage that can be repaired.

4.2 Methods of Seismic Analysis of Structure

For the seismic study of structures, various methods of varying complexity have been devised.

They can be classified as follows.

1. Linear and nonlinear Static Analysis
2. Linear and nonlinear Dynamic Analysis

4.2.1 Methods of static analysis

Equivalent static analysis is used to evaluate the seismic activities on a part of a structure while considering a design seismic coefficient. Factors such as, are included in the design seismic coefficient.

1. Soil foundation factor
2. Response reduction factor
3. Zone factor

4.2.2 Equivalent static analysis

The dynamic character of the load must be considered in any design against earthquake effects. Analyzing simple regular structures with analogous linear static methods, on the other hand, is frequently sufficient. Most codes of practise allow this for typical, low to medium rise buildings, and it starts with a calculation of peak earthquake load as a function of the code's parameters. The static method is the easiest because it involves less processing work and is based on formulas from the practise code. The design base shear is computed for the entire building first, and then dispersed along the building's height. Equivalent static analysis can thus be useful for low to medium-rise buildings with few coupled lateral torsional modes, where just the first mode in each direction matters. Tall buildings, such as those exceeding 75 metres tall, where second and higher modes are essential, or buildings having torsional effects, are less suited for the procedure and require more advanced methods.

4.2.3 Nonlinear static analysis

It is a practical method for estimating deformation and damage patterns in structures by analysing them under constant vertical loads and gradually increasing lateral stresses. The behaviour of the structure is represented by a capacity curve that reflects the relationship between the base shear force and the displacement of the roof in nonlinear static analysis. Pushover Analysis is another name for it.

4.2.4 Methods of dynamic analysis

Free vibration analysis is used in structural dynamic analysis to determine the mode shapes and frequencies. The response spectrum or acceleration/force time history of the structure can be used to assess seismic loading.

The Dynamic Analysis Procedures can be characterized as:

1. Time history analysis for linear and nonlinear structures
2. Response spectrum analysis for linear structure

5 Design Requirements of Shear Wall as per IS 13920:2016

1. The requirements of this section apply to the shear walls, which are part of the lateral force resisting system of the structure.
2. The thickness of any part of the wall shall preferably, not be less than (a) 150 mm. (b) 300 mm for buildings with coupled shear walls in any seismic zone

   Minimum thickness provided must conform to the fire resistance requirements based on occupancy laid down in IS 456.
3. Special shear walls shall be classified as squat, intermediate or slender depending on the overall height hw to length Lw ratio as
   a. Squat walls: hw / Lw <1,
   b. Intermediate walls: 1 ≤ hw / Lw ≤ 2, and

c. Slender walls: hw / Lw > 2.

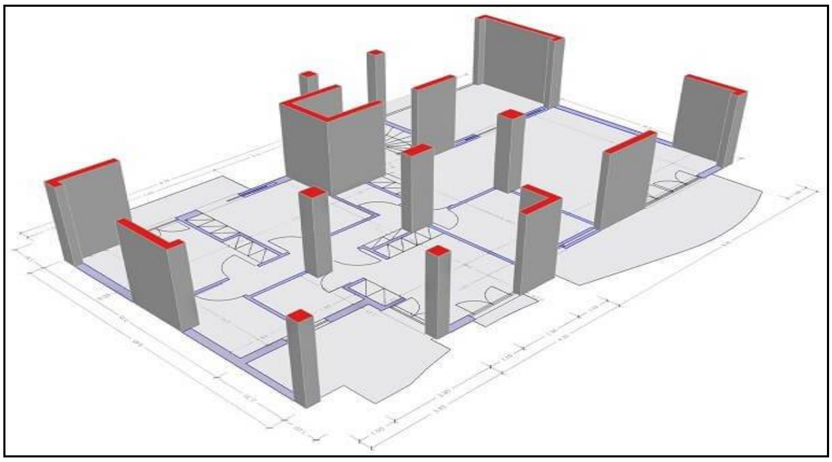

Figure 2. Shear wall Locations

4. The effective flange width, to be used in the design of flanged wall sections, shall be assumed to extend beyond the face of the web for a distance which shall be smaller of (a) half the distance to an adjacent shear wall web, (b) 1/10th the total wall height. and (c) actual width available.
5. Shear walls shall be provided with reinforcement in the longitudinal and transverse directions in the plane of the wall. The minimum reinforcement ratio shall be 0.0025 of the gross area in each direction. This reinforcement shall be distributed uniformly across the cross section of the wall.
6. If the factored shear stress in the wall exceeds 0.25 or if the wall thickness exceeds 200 mm, reinforcement shall be provided in two directions in the plane of the wall.
7. The diameter of the bars to be used in any part of the wall shall not exceed 1/10th of the thickness of that part.
8. The maximum spacing of reinforcement in either direction shall not exceed the smaller of $lw/5$, $3tw$ and 450 mm; where ‘lw’ is the horizontal length of the wall and ‘tw’ is the thickness of the wall web.

V. MODELING AND ANALYSIS

The suggested study is conducted in the P+15 storey building. The modelling and analysis are done with the help of the ETABS 2019 program. ETABS is a fully integrated software for RC structure analysis and design.

5.1 Problem Statement

A P+15-storey RC building is considered in this problem. The plan dimensions in the X and Y directions are 24.05 and 28.10 meters, respectively, while the building's overall height is 51 meters. The building's foundation stratum is believed to be hard and available at 1.5 meters below ground level. At the base, the columns are presumed to be fixed. IS 13920 – 2016 and IS 13920 – 1993 were used to examine the building for different seismic loading positions. For India's earthquake zone III, a structure with effective beam column dimensions is investigated.

5.1.1 Preliminary data

1. No. of floors-16 floors (P +15)
2. Ground storey height-3 m
3. Floor to floor height-3 m
4. Plan dimension along X-24.05m
5. Plan dimension along Y-28.10m
6. Shear wall thickness-320 mm
7. Slab thickness-150 mm
8. Size of beam-230 mm X 600 mm
9. Sizes of column-1000 mm X 230 mm
10. Grade of concrete and steel-M30 and Fe500

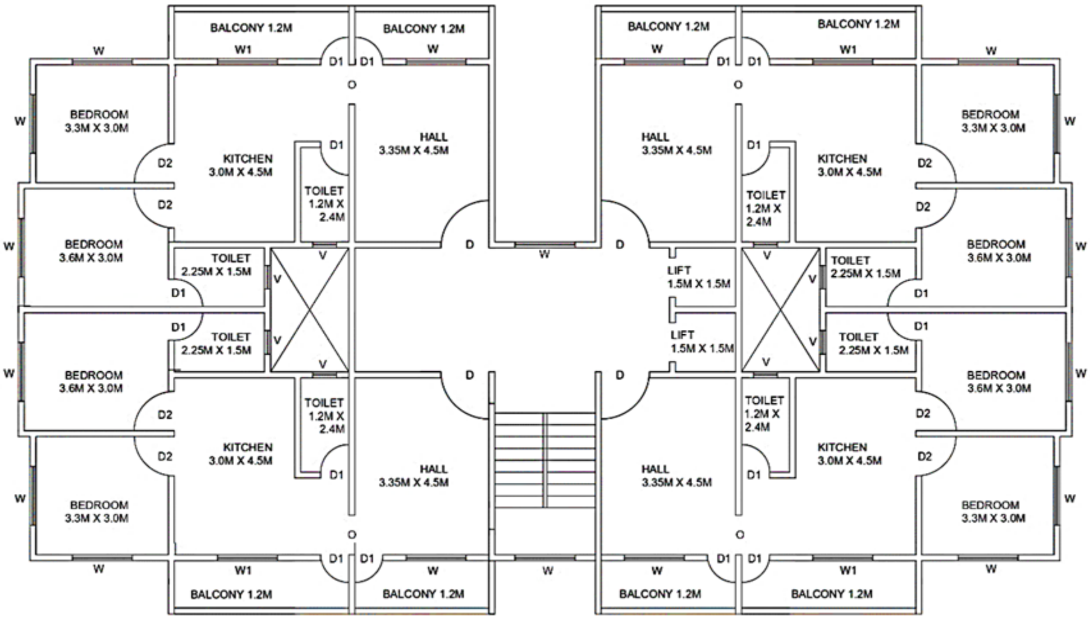

FIGURE 3. TYPICAL FLOOR PLAN

5.1.2 Structural related general information

Table 4.1: Earthquake parameter

Sr. No.	Parameters	Code Provision
1	Type of structure	RC framed structure
2	Total No. of Slabs	16 Slabs
3	Number of Parking Floors along with height of floor	Ground Floor - 3.0 m
4	Number of Residential Floors	15 floors (Typical -3.00 m)
5	Total height of building above foundation top level	51 m
6	Height of building above ground level	49.2 m
7	Type of building	Residential
8	Seismic zone	III
9	Importance factor	1.2
10	Response reduction factor	4
11	Soil type	Hard
12	Damping coefficient	5%

5.1.1 Loading Parameters

Dead loads and live loads on different units of structure as follows :

Slabs 125 mm thk	0.125X25	3.125 kN/m^2
Slabs 150 mm thk	0.150X25	3.750 kN/m^2
Slabs 175 mm thk	0.175X25	4.375 kN/m^2

a) Typical Residential Floors

Floor Finishes	=	0.050 X 20	1.00 kN/m^2
Total Superimposed Dead Load			1.00 kN/m^2

Live Load	=		2.0 kN/m^2

b) Core Area / Corridors / Lobby /Staircases

Superimposed Dead Load: -				
Floor Finishes	=	0.050 X 20	=	1.00 kN/m^2
Total Superimposed Dead Load			=	1.00 kN/m^2
Live Load	=		=	3.0 kN/m^2

c) Wet Area / Toilets

Superimposed Dead Load: -				
200 mm sunk	=	(0.2 x 20)	=	4.0 kN/ m^2
Total Superimposed Dead Load			=	4.0 kN/m^2
Live Load	=		=	2.0 kN/ m^2

f) Balcony

Superimposed Dead Load: -				
150 mm sunk	=	(0.15 x 20)	=	3.0 kN/ m^2
Total Superimposed Dead Load			=	3.0 kN/ m^2
Live Load			=	**3.0 kN/ m^2**

g) For Roof Floors

Superimposed Dead Load: -				
Waterproofing average filling 1 mm	=	(0.125 X 20)	=	2.5 kN/ m^2
Total Superimposed Dead Load			=	2.5 kN/ m^2
Live Load			=	1.5 kN/ m^2

j) For Staircase

Superimposed Dead Load: -				
Superimposed Dead Load			=	2.5 kN/ m^2
Live Load			=	3.0 kN/ m^2

k) For LMR and OHWT

Dead Load 200 KN point load is assigned on lift shear wall for LMR.

Dead Load 200 KN point load is assigned on staircase shear wall for OHWT.

Superimposed Dead Load: -

Floor Finishes	=	**0.050 X 20**	=	**1.0 kN/ m^2**
Live Load			=	**5.2 kN/ m^2**

4.3.3 Grade of concrete and steel for structural members

Table 4.2 -Grade of concrete

Sr. No.	**Levels**	**Wall**	**Column**	**Beams**	**Slabs**
1	**Footing top to 5th slab**	**M35**	**M35**	**M35**	**M35**
2	**6th slab to 10th slab**	**M30**	**M30**	**M30**	**M30**
3	**11th slab to 16th (Roof) slab**	**M25**	**M25**	**M25**	**M25**

ii) Grade of Concrete for Footing - M25

iii) Grade of Steel - Fe500 (D) with minimum Elongation 14.5 % (Confirming to IS 13920 and IS1786

iv) PCC Grade -M15

5.1.2 Beam Sizes

At plinth level tentatively beam sizes- 300 mm X 400 mm

At typical level tentatively beam sizes- 300 mm X 600 mm, 300 mm x 450 mm, 300 mm x 400 mm

External & Internal Walls

External & Internal walls are light weight AAC blocks having maximum density 7.5 kN/m^3.

AAC block Masonry Walls Loading:

a. 125 thk wall = ((0.15 X 7.5) + (0.05X20) X 2.40 = 3.90 kN/ m^2

Environmental Exposure Conditions

As per exposure conditions given in IS 456:2000

Sub Structure: All Substructure elements -Moderate
Super Structure: All external columns and peripheral beams- Mild

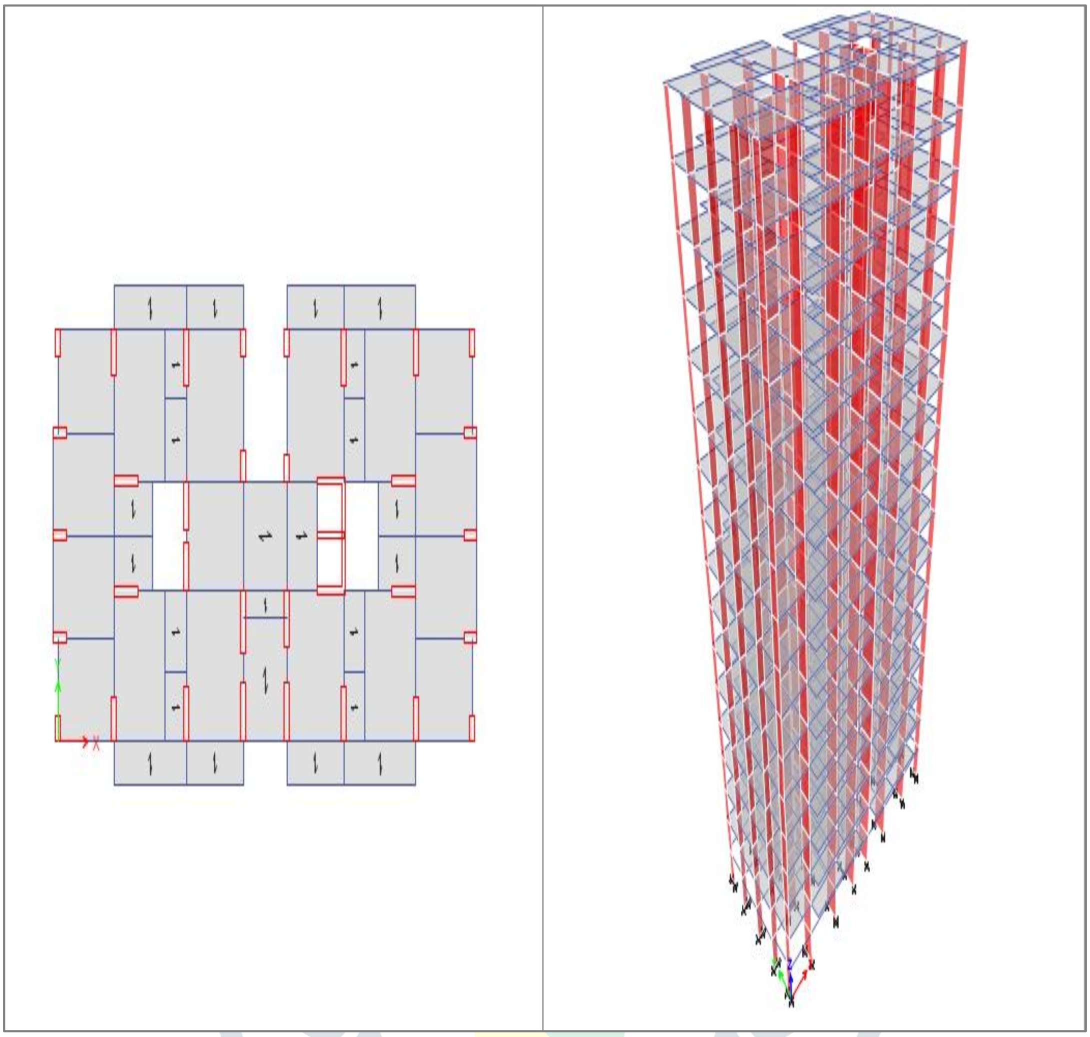

FIGURE 4 LAYOUT AND ETABS MODEL

VI. RESULTS AND DISCUSSION

The following results are mostly a comparison of parameters governing earthquake design using the IS 13920-2016 code and the IS 13920-1993 code. The results of the seismic analysis and design of the P+15 RC framed Structure are discussed and listed below. The tables contain the Base Shear, storey drift, roof displacement, quantities, and cost analysis results. Graphs are produced after the findings have been tabulated to give a clear picture of the percentage analysis. The discussion is based on the results gathered.

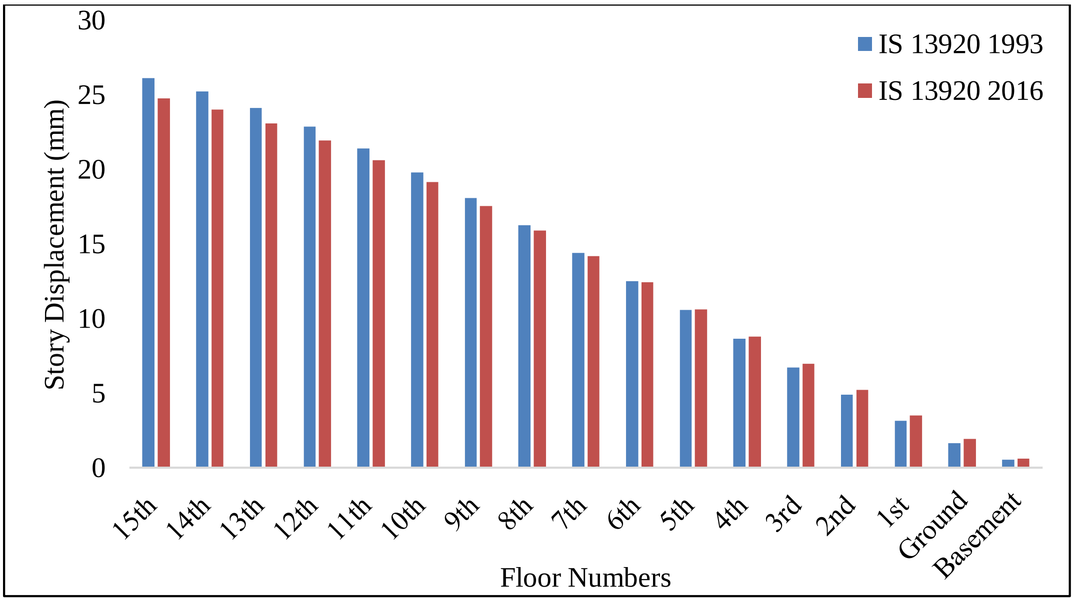

Chart 5- Storey Displacement- EQX

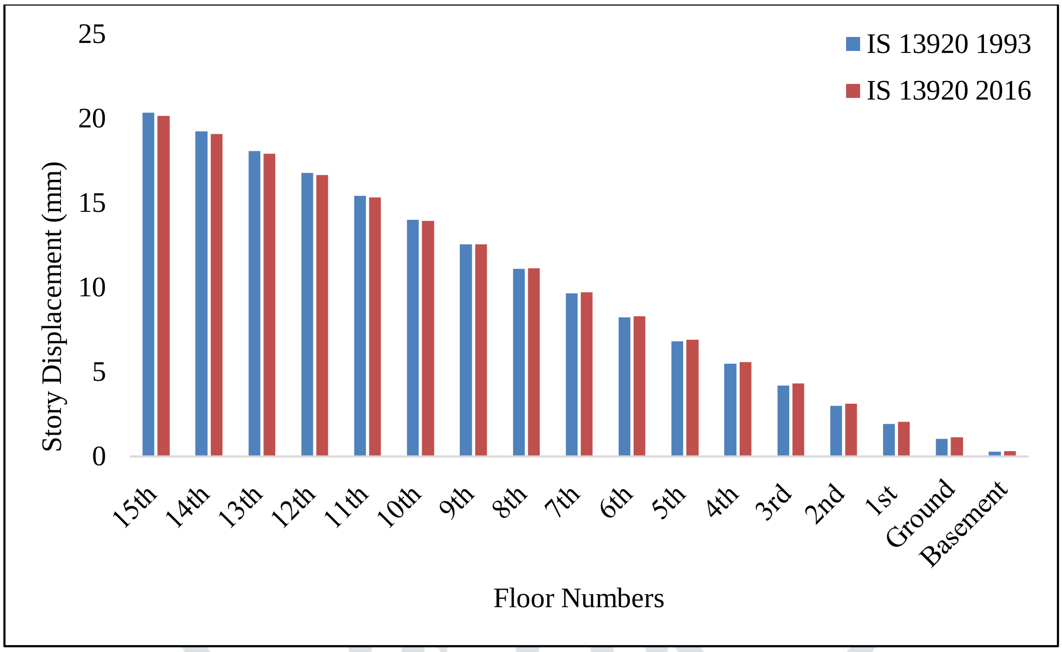

Chart 5.4 - Storey Displacement- EQY

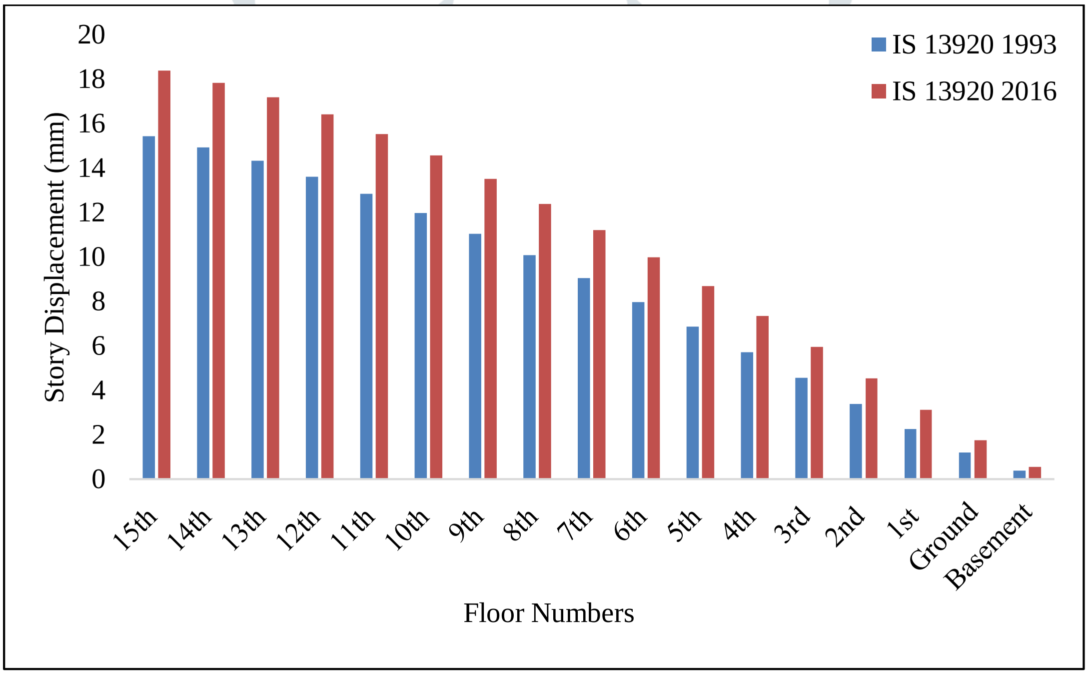

Chart 5.5 -Storey Displacement- Spec X-X

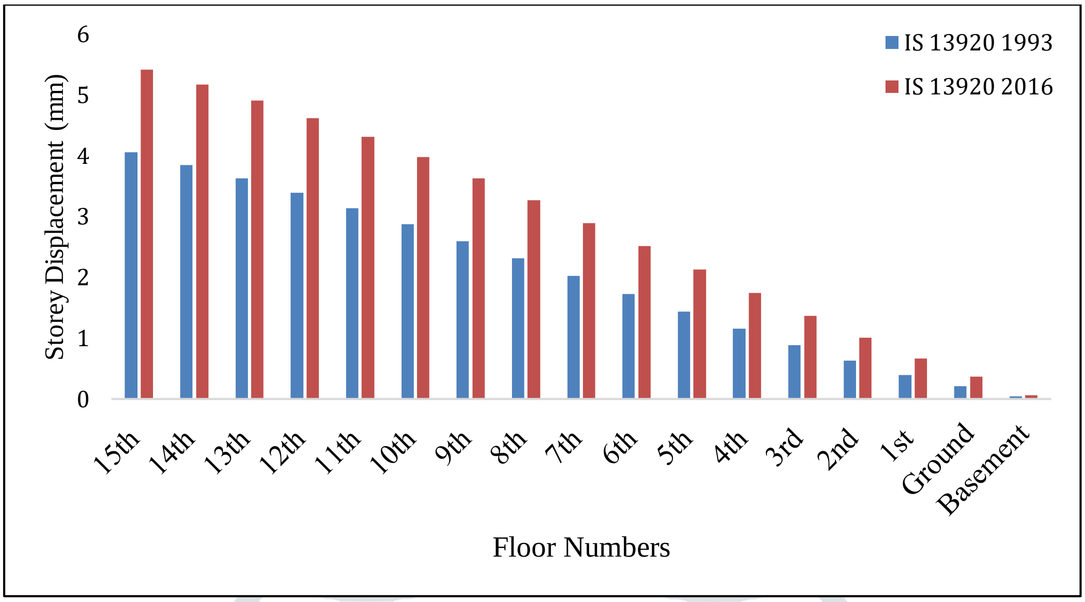

Chart 5.6 -Storey Displacement SPEC X-Y

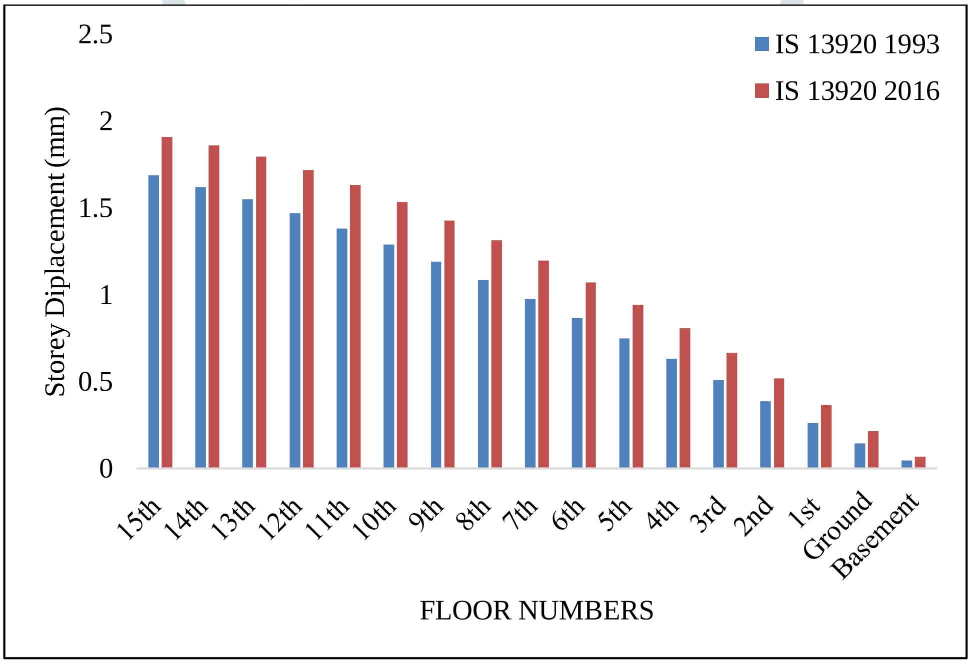

Chart 5.7 -Storey Displacement- Spec Y-X

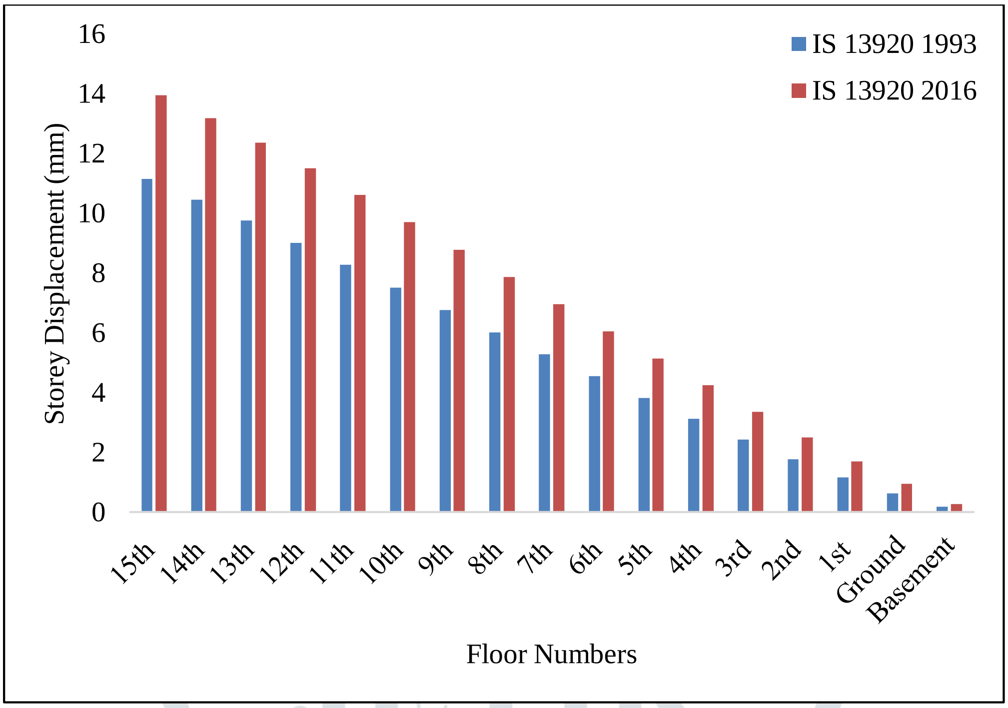

Chart 5.8 -Storey Displacement Spec Y - Y

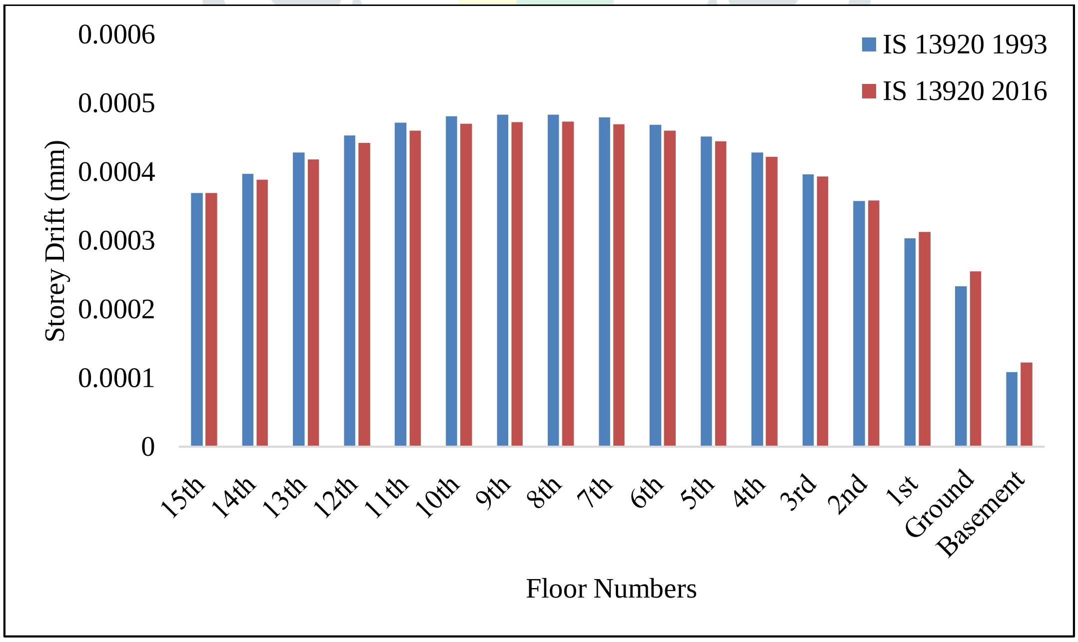

Chart 5.10 -Storey Drift - EQY

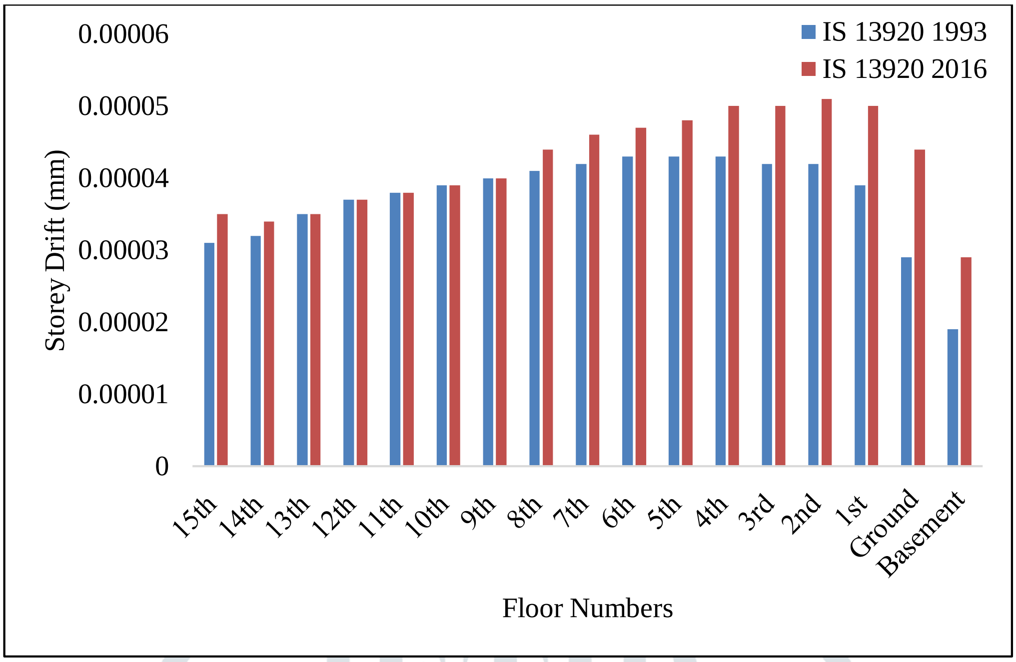

Chart 5.13 -Storey Drift SPEC Y- X

CONCLUSION

IS 13920 – 2016 contains major revisions to the Ductile design and detailing clauses, including changes to the cross section, aspect ratio, minimum dimensions of column, and shear design of the Beam Column Joint. The following are the findings of the current research.

1. The most important change in the revised code of 2016 is that the minimum size of column to be kept is now 300 mm against 200 mm as per the earlier code. This provision is of special importance to architects as they have to prepare architectural drawings accordingly. Structural designer has also to take care while providing the beam reinforcement as the minimum size of the column should also not to exceed 20 times the largest bar of the beam at the joint.
2. The incorporation of strong column-weak beam theory in the revised code will result in significant changes in beam-column design.
3. For high-rise buildings, the need of shear design for beam-column joints remains applicable under the updated clauses in IS 13920.
4. In actual practice load transformation path is slab to beam, beam to column and column to footing. In this path load concentrate at beam column joint, leading to rotation due to framing action, to avoid this we need to follow revised IS code.
5. The variation in storey displacement is non-uniform from bottom to top of the building.
6. The resistance to seismic effect of structure depends upon transverse area of structure. By varying concrete grade, we can keep same dimensions of vertical members throughout the structure hence transverse area will increase.
7. The structure can suffer more displacement to reduce the probability of collapse due to ductile detailing of joints, even though the reduction in deflection is not significant

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